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A REMARKABLE PUMPING PERFORMANCE AT THE NORTHEAST PUMPING STATION, MINNEAPOLIS[1]

BY F. W. CAPPELEN[2]

The object in presenting this paper is to show the great advance that has been made in the art of designing and constructing electrically driven centrifugal pumping machinery in the last few years. Extracts from the specifications upon which the city of Minneapolis received bids are presented and from the contract and proposal from the pump manufacturer, as well as his exceptions to the city's specifications, for the benefit of engineers who may have similar work under consideration.

The efficiency test is presented, as well as actual operation data for a period of the first three months after the test run, as well as data for the first nine months of operation, showing the maintenance of the high efficiency guaranteed by the pump manufacturer.

The installation, as well as the test, was in charge of J. A. Jensen, supervisor of the Minneapolis Water Works, and E. C. York, chief engineer of the Minneapolis pumping stations. The test, as far as the city is concerned, was in full charge of F. W. Springer, professor of electrical engineering at the University of Minnesota, and William Salt was the representative of the pump manufacturer.

EXTRACTS FROM THE DETAILED SPECIFICATIONS FOR ELECTRIC MOTOR DRIVEN CENTRIFUGAL PUMP

The City of Minneapolis, Minnesota, proposes to purchase one 30,000,000 gallon electric-motor-driven centrifugal pump, to be placed in the Northeast Pumping Station. The pump must deliver 30,000,000 gallons of water in 24 hours against an average dynamic head of 250 feet, in which the suction lift, not to exceed 16 feet, is included.

These specifications are intended to include a complete equipment, erected on foundation furnished by the City of Minneapolis, ready for suction and discharge pipe connections furnished by the City of Minneapolis, and ready for electrical energy. The City of Minneapolis will make the connections to the suction and discharge piping, and the pump manufacturer will be expected to have the pump equipment ready with suction and discharge flanges drilled for standard connections.

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[1] Read before the Minnesota Section, May 3, 1919. Discussion of this paper is invited and should be sent to the Editor.

[2] City engineer, Minneapolis, Minn.

It is the present intention of the City of Minneapolis to purchase the pump prior to November 15, 1916. The pump is to be delivered, erected and connected, in a complete manner, ready for tests within six months thereafter, or on May 15, 1917. A forfeit of $100 per day will be made and deducted from the contract price, as liquidated damages, for each day, after the above specified time of completion expires. The city reserves the right to operate said pump for sixty days, pending the final acceptance and testing of the pump by the city.

The word "Pump" refers to and means the complete pumping unit with cast-iron base, rotor, motor, stator, controller, switchboard, and all accessories necessary for the ordinary operation of the pump. The word "Efficiency" refers to and means the combined or total efficiency of the pump with its electric motor. The words "Dynamic Head" refers to and means the difference in levels, in feet, between the surface of the water in the city water settling reservoir, and the surface of the water in the river supply well near the pump suction main, plus the friction head in feet. The term "Manufacturer" or "Contractor" shall be deemed to mean the party whose bid has been accepted for the installation of the pumping unit.

The pump will take its water from the Mississippi River and deliver the water through 50-inch and 54-inch pipe lines to the settling reservoir, at the Filtration Plant, under average dynamic head of 250 feet.

Motor. The manufacturer of the pump equipment is to furnish an electric motor for the driving of the pump. The motor is to be of the horizontal, direct-connected, three phase, 60-cycle, 2200-volt, slip-ring, induction type. The motor shall be capable of starting the pump from rest when the pump is primed and when the check or gate valve in the discharge is closed, and bring the pump to full speed without drawing more than 150 per cent of full-load current from the source of supply. A modern motor is required, and one having an efficiency on full load of at least 94 per cent. The short-circuited rotor losses are to be reduced to a minimum, during normal running. Pedestal type ring-oiling bearings are required, that can be removed by removing bearing caps.

(A) The slip of the motor from synchronous speed on full pump load, namely; at the rate of 30,000,000 gallons per day against 250 feet dynamic head, shall not exceed 1.7 per cent of synchronous speed.

(B) The rise in temperature of any part of the motor after 24-hours run with full pump load, shall not exceed 40° Cent. above surrounding temperature.

(C) American Institute rules shall govern for definitions and for motor tests.

Switchboard. One switchboard panel, to support meters and controller, is to be erected and connected in the pumping station. This panel is to be made of either two or three slabs of blue Vermont marble on which the following are to be mounted.

1 Oil switch, for a 2200-volt, three-phase, 2000-kilovolt-ampere circuit, with overload and no-voltage release, and with interlocks to the controller switches.

3 Ammeters; 1 voltmeter; 1 cyclemeter; 1 power-factor meter.

1 Curve-drawing wattmeter, with 1500-kilovolt scale, and record sheets for one year of continued use.

1 Recording wattmeter to integrate the kilowatt-hours used for pumping service.

1 Westinghouse controller, or equal, with rheostats for starting the motor.

Necessary transformers; two lamp fixtures; wiring; card racks; panel supports; rheostat supports, etc., to make a complete outfit.

Wiring is to be furnished and connected between the switchboard, controller, rheostats and the motor, and this wiring is to be paper insulated, lead covered, pot-leaded, laid in fibre conduit, and the insulation is to conform to the ordinances regulating electrical work in the City of Minneapolis. The meters are to be carefully calibrated and sealed and must be accompanied with a certified calibration curve or table.

Pump Rotor. The rotor for the pump is to consist of a forged steel shaft on which a two-stage bronze impeller is to be mounted. That part of the shaft which is exposed to rusting by water, including that part running through the stuffing boxes, is to be protected by a bronze sleeve. The impeller itself is to have balancing chambers, and at the end of the shaft a marine-type thrust bearing is to be provided. The impeller is to work in perfect rotative balance.

The bearings are to be babbitt-lined, and of the double ring-oiling pedestal type, that can be removed without disturbing any part of the pump except the bearing caps.

The shaft coupling between the motor and the pump rotor is to be of the flexible type.

The stuffing boxes are to be of ample length, packed with non-rusting, high-pressure, hydraulic packing. The glands are to be provided with water seal and necessary connections therefor. The necks and glands are to be lined with brass.

One extra set of impellers and also a complete set of division rings are to be furnished with the pump.

Pump stator. The stator of the pump shall be a rigid casting properly designed to hold the shaft and to guide the water from the impellers. A casting which is made in two parts, rather than four or more parts, and a casting which can be opened without dismantling the suction and discharge pipe connections, is preferred. The inside of the stator is to be protected with an anti-rust metallic paint.

Between the rotor and the stator, the necessary packing rings of brass are to be provided, to seal the water pressure from the impeller.

The pump stator and the motor are to have one cast-iron integral base.

Priming and drain connections are to be arranged and fitted between the pump stator and the source of supply and discharge. An ejector or vacuum equipment will be used and furnished by the City of Minneapolis.

The flange connections at the pump, for the discharge and suction piping, are to be drilled by the manufacturer.

Guarantees. A diagram or table is to be furnished by the pump manufacturer, at the time of making the proposal to the City of Minneapolis, showing the guaranteed capacity of the pump in gallons per day, and the guaranteed efficiency of the pump when working at rated speed, with dynamic heads varying from 240 to 275 feet, with a maximum efficiency when head is 250 feet. The efficiency should be fairly uniform over the full range of dynamic head.

Tests. The said pump is to be erected and connected complete by the pump manufacturer or contractor, after which, the service and the efficiency of the pump are to be not only tested but passed upon by the representative of the contractor or manufacturer, and the representative of the City of Minneapolis, appointed by the Water Works Committee of the City Council, for the purpose of determining whether or not the guarantees for the capacity and efficiency as herein specified, are fulfilled. In case the representative of the company and the representative of the city cannot agree, then, in that case, said representatives shall appoint a third man, who shall be a competent engineer; and the decision of two of the three judges thus appointed shall be final and binding both upon the city and the manufacturer or contractor.

Should the representatives of the city and the manufacturer or contractor be unable to agree, then, in that case, a Judge of the District Court of Hennepin County, shall appoint a third man, who shall be a competent engineer, to act as arbiter between the manufacturer and the city, and under the same conditions as above set forth. The appointment by a judge of the District Court, shall only be made upon 10 day's notice by either party to the other, or by mutual agreement.

For the purpose of testing the pump, a Venturi meter, manufactured by the Builders Iron Foundry, shall be used and accepted, both by the city and the manufacturer, as the measuring device for the purpose of ascertaining the amount of water pumped, that is, for the purpose of determining the efficiency and service of the pump.

The accuracy of this Venturi meter shall be deemed to be correct; unless the pump manufacturer is able to establish, by tests or other satisfactory evidence, that the meter, either in whole or in part, is inaccurate, and the Venturi Meter in this proposal is deemed to be both the tube, so called, and the recording device. Provided, the company furnishing the meter to the city shall guaranty the Venturi meter, including the tube and the recording device, to be accurate within one and one-half per cent. That is to say, the service and delivery of the pump are to be accepted and tested upon the basis of the meter, subject to provisions hereinbefore set forth.

All other meters used in testing shall be checked by and at the expense of the City of Minneapolis, and certificates therefor shall be acknowledged.

Efficiency. In case the efficiency of the pump shall be determined to have exceeded 76 per cent, the manufacturer furnishing said pump shall be entitled to a bonus of $500 for each one per cent or fraction thereof, over and above the contract price. In case the efficiency of the pump shall be found to be less than 76 per cent, then, in that case, the manufacturer or contractor furnishing said pump, shall forfeit to the City of Minneapolis, to be deducted from the contract price, $500 for each one per cent or fraction thereof. Provided, however, that the total amount of bonus shall not exceed $2400. However, the pump shall not be accepted if it falls below 72 per cent.

Payments. The manufacturer shall be entitled to full compensation for the pump furnished, at once, after the pump has been tested and accepted by the Water Committee of the City Council of the City of Minneapolis.

Reservations. The right is reserved to reject any or all proposals, or any part of any proposal, and to make minor modifications in the specifications prior to the acceptance of a proposal.

EXTRACTS FROM CONTRACT WITH THE MINNEAPOLIS ELECTRIC EQUIPMENT COMPANY

The party of the first part hereby agrees to manufacture, furnish, deliver and install for said second party at the Northeast Pumping Station, in the city of Minneapolis, Minn., on foundations to be furnished by said second party, two 24-inch DeLaval single-stage pumps with equipments, connected in tandem and operating in series at a speed of approximately 590 R.P.M., said pumps to be designed to deliver 30,000,000 gallons for 24 hours, against a total head of 250 feet, including 16 feet suction lift, direct-connected to an 1800-H.P. 600-R.P.M. form "P," 2200-V., General Electric motor and General Electric switchboard and instruments throughout and General Electric drum controller, and furnish all the material and do and perform all the work and labor necessary therefor, all in strict conformity with the plans and specifications for said pumps prepared by said second party as modified by the proposal and specifications for said pumps submitted by said first party and the addenda attached to said specifications, ... and to complete the installation of said pumps and equipments by the 1st day of March, A.D. 1918, all for the sum and price of $26,000, ...

Said first party further agrees and guarantees that the pumps and equipments furnished by said first party under this contract shall and will deliver not less than the quantities given in the following table, when 3-phase, 60-cycle, 2200 volt current is furnished at the terminals of the motor, the heads as given being understood to be total heads developed by the pumps, measured by means of calibrated gauges located at the suction and discharge nozzle of the pumps, and corrected for difference in elevation, if any. The efficiencies guaranteed are based on operating the pump at total head as specified and at a discharge rate not less than the quantities stipulated, and it is understood that the suction lift shall not exceed 16 feet. Said table above mentioned is as follows:

Total head in feet	*Million gallons per day*	*Combined efficiency of pump and motor*
275.0	24.0	74.3
262.5	27.4	75.9
250.0	30.0	76.0
237.5	31.8	75.2

EXTRACTS FROM LETTER ACCOMPANYING PROPOSAL OF MINNEAPOLIS ELECTRIC EQUIPMENT COMPANY

The centrifugal pumps offered to the City of Minneapolis will be manufactured by the DeLaval Steam Turbine Company, Trenton, N. J., a concern devoted exclusively to the manufacture of rotating apparatus, including centrifugal pumps, steam turbines, reduction gears and blowers. All renewable parts are made to limit gauges so that replacement can be made in the field by comparatively inexperienced men and without the necessity of doing any machine work. This applies particularly to such items as impellers, impeller wearing rings, case protecting rings, shaft sleeves, bearings, glands, etc.

The proposal is not based on the detailed specifications of the City of Minneapolis. The proposals which we are making are subject to prompt acceptance by the City and prices named are subject to change without notice on and after November 15th, 1916.

We will guarantee to have the equipment covered by the attached proposals delivered, erected and connected in a complete manner, ready for attachment of suction and discharge piping, and ready for electrical connections within fifteen months from date of receipt of signed copy of proposal. The specified date for completion of the work is subject to any delays on your part in supplying us with necessary data or any changes in same, as well as to delays due to fires, floods, strikes, accidents or other causes beyond our reasonable control, and subject to such delays we are willing to agree to forfeit $100.00 per day for each day after the above specified time of completion expires, but in no case shall we be liable for consequential damages.

The word "Efficiency" is to mean the combined efficiency of the pump with its electrical motor, based on electrical imput being measured at motor terminals, total head being determined by calibrated gauges located at the suction and discharge nozzles of the pump and corrected for difference in elevation, if any, and rate of discharge being determined by means of a venturi meter, which the City guarantees to be correct within 1½ per cent.

Your specifications call for 2000-KVA circuit breaker. This would necessitate using an 800 ampere circuit breaker. We have disregarded this, and are furnishing a 500 ampere oil circuit breaker.

The rotating element of the pump will consist of two forged steel shafts on each of which will be mounted a single stage bronze impeller. The shafts will be protected from wear and contact with water by removable protecting sleeves, extending from the impeller to the outer ends of the stuffing boxes, completely covering the shaft and providing a bearing surface for the packing.

Each impeller will be of the double suction type, completely balanced within itself.

Each shaft will have a marine type of thrust bearing at one end. Each shaft will be carried in two bearings with ring oilers. The bearing shells will be held in bearing brackets bolted to the pump casing. The bearing shells will be babbitt lined and may be removed without disturbing any part of the pump except the bearing caps. Necessary couplings will be furnished and they will be of the flexible type.

The stuffing boxes will be arranged for soft packing and are provided with water seals and all necessary drip boxes and drainage openings.

The glands are of the split type and can be removed without disturbing other parts, thus facilitating the examination or replacement of the packing. The glands will be of solid brass; the stuffing boxes will not be lined with brass, as this is unnecessary.

The impellers will be of bronze; the impeller protecting rings will be of bronze, and the case protecting rings will be of brass.

The stationary portion of the centrifugal pumps will consist of two pump casings, connected together by suitable series piping, which is furnished under this contract. Each pump casing will consist of two complete parts, separated horizontally in the plane of the center line of the shaft by a flat joint scraped to fit and maintained air and water tight by a thin paper gasket. The lower half of the casing will contain both suction and discharge openings so that the pumps can be opened without disturbing suction and discharge piping connections.

We cannot agree to furnish detailed drawings of all parts of the equipment, but can probably furnish drawings of such parts of the machines which can be made by the City or for the City by the ordinary machine shop. Pump case and pump impeller drawings will not be furnished under any consideration.

It is intended that the machinery is to be free from latent defects in material and workmanship, and should any part of it be found, within one year from date of arrival f.o.b. cars Minneapolis, to have been defective at the time furnished, we will repair said part f.o.b. Manufacturer's Works, or will furnish without charge f.o.b. Manufacturer's Works, similar part to replace it, provided the original part is returned to Manufacturer's Works, freight prepaid, and Manufacturer's inspection establishes the claim. We will make no allowance for repairs or alterations unless same are made with our written consent and approval.

Payment for the equipment shall be made as follows:

Twenty-five per cent cash on shipment of apparatus, as evidenced by presentation of bill of lading.

Twenty-five per cent cash on completion of erection ready for piping and electrical connections.

Fifty per cent cash sixty (60) days after second payment becomes due, provided the equipment has met all the conditions and stipulations of this proposition.

It is mutually agreed that if the erection of the equipment is delayed by the City, the second payment is due thirty days after arrival of the equipment f.o.b. cars Minneapolis, and final payment is to be made in not to exceed 180 days after arrival of apparatus f.o.b. cars Minneapolis. If the starting and testing of the equipment is delayed for any reason beyond our control, final payment is to be made in not to exceed sixty days after completion of erection ready for piping and electrical connections.

EXTRACTS FROM SPECIFICATIONS PREPARED BY GENERAL ELECTRIC COMPANY

Pump motors. Power factor and efficiency guarantees will be in accordance with detailed specification sheet which is included. The motor will operate for 24 hours at normal rated output with temperature rise in any part not exceeding 40° Cent.; and for 2 hours at 25 per cent overload without injury. The overload heat run will immediately follow the normal load heat run.

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SPECIFICATION SHEET FOR INDUCTION MOTORS

CLASSIFICATION

	Type	Poles	H. P.	Sny. speed R. P. M.	No. of			Form
					Volts	Phases	Cycles	
1	I	12	1800	600	2200	3	60	P

TEMPERATURES AND INSULATION TESTS

Temperature rise by thermometer Deg. C.			Factory high potential tests between primary coils and frame A-C voltage for 1 min.	Full load speed R. P. M.
	Full load until constant	125% load 2 hrs.		
1	40	Without injury	6000	591

The overload temperature is based on making the overload run immediately following the full load run.

The efficiency and temperature rise are based on full rated voltage and frequency.

The temperature rise is further based on an ambient temperature of 25 deg. C., normal conditions of ventilation and an altitude of 1000 meters (3300 feet) or less; corrections for variations from this altitude will be made by changing the observed rise of temperature by one per cent for each 100 meters (330 feet) deviation in altitude above 1000 meters.

EFFICIENCIES, POWER-FACTORS AND OVERLOADS

	Full load		¾ Load		½ Load		Maximum running torque, % full load torque
	EFF.	P-F.	EFF.	P-F.	EFF.	P-F.	
1	94	89	93.5	87	91.5	82	225

ARRANGEMENT AND APPROXIMATE NET WEIGHTS

	Connection belted, direct geared, chain	No. of bearings	Motor complete
1	Direct	2	24300

……

Temperatures are to be taken by thermometer and rises will be based on a room temperature of 25° Cent. For room temperatures other than 25° Cent.

corrections will be made according to the Standardization Rules of the American Institute of Electrical Engineers.

Insulation tests will be in accordance with the Standardization Rules of the American Institute of Electrical Engineers.

The motor will be of the constant-speed induction type with horizontal shaft and phase-wound rotor. When running at full speed and full rated voltage motor will be capable of delivering its full rated horsepower. Motor will be furnished without base or coupling, but with two pedestal-type bearings and shaft extended for direct coupling to pump through a flexible coupling which is not included with the motor. The stationary member, or stator, will be the primary, and the rotating member, or rotor, will be the secondary.

Stator. The frame will be so proportioned that the laminations and windings will be supported with practically no deviation from a circle. The frame will be of the enclosed box type with open end shields, so constructed as to allow the free circulation of air around the winding.

The core will be built of high-grade thin sheet iron laminations carefully selected and treated so as to reduce core losses. It will be provided with slots on the inner circumference to receive the windings.

The winding will consist of copper conductors form wound, thoroughly insulated throughout their length, moulded to exact size before being assembled in the slots, and held firmly in place by means of wedges driven into grooves in the teeth. Each coil will be a complete unit in itself, so that in the event of any coil being injured it can be removed readily and another substituted by removing a few adjacent coils.

The insulation of the coils will consist of layers of fabric treated with a suitable insulating compound. Special treatment will be given this insulation which will make its quality such that it will be particularly able to resist oil and moisture and will not deteriorate when subjected to oil and moisture in connection with the temperatures herein specified.

Rotor. The rotor spider will be made of cast steel so designed as to hold the magnetic core rigidly in place. The magnetic core will be built up of high-grade thin sheet iron laminations selected and treated the same as specified for the stator. It will be provided with slots on its outer circumference to receive the windings.

The windings will consist of copper bars thoroughly insulated throughout their length and wedged tightly under the overhanging parts of the teeth, which will be so shaped as to prevent their being displaced by centrifugal force. The ends of the bars outside the slots will be further protected from displacement by being bound tightly upon the projecting ends of the flanges which hold the punchings in place. The windings will be so arranged that in the event of any bar being injured it can be removed readily and another substituted.

The insulation will consist of layers of fabric treated with a suitable insulating compound, the quality of which will be such that it will not deteriorate when subjected to temperatures herein specified, nor will any permanent injury result from exposure to dampness.

Collector rings. The collector rings will be of copper alloy placed in an accessible position between the bearing and the spider. The rings will be carefully insulated from each other and from the shaft, and so mounted that the air can freely circulate around them giving thorough ventilation. The brushes will be pressed against the rings by springs in such a manner as to give a uniform pressure. Provision will be made for short circuiting the collector rings on the inside surface when the motor has come up to speed, and at the same time the brushes are lifted from the collector rings, thus eliminating wear and resistance and brush contact losses.

Shaft. The shaft will consist of one piece forged steel, accurately finished to gauge. It will be of sufficient size to perform the work specified and prevent nundue deflection.

Bearings. The bearings will have cast iron shells lined with hard babbitt and will be of the ring oiling type. The bearings will be self-oiling and self-aligning and will have ample surface to insure cool running. The oil reservoirs will be capable of holding a liberal supply of oil, and convenient gauges for indicating the height of the oil and outlets for drawing it off will be provided.

Control. A drum type controller will be mounted back of the switchboard and will be connected to a handwheel on the front of the panel through bevel gearing. This controller will cut out the resistance in the rotor circuit in fourteen steps. The resistance will be of the cast grid type.

Interlocks will be provided so that, in the event of the oil circuit breaker being tripped on overload or low voltage, it cannot again be closed until the controller has been brought to the "off" position and the short circuit removed from the brushes.

The acceptance test was run on May 28 and 29, 1918. All tests were conducted strictly according to the requirements of the contract. No essential compromises were necessary.

Three sets of watthour meters, each complete with suitable current and potential transformers, were read during the test. In addition a portable set of standard instruments was used, including two single-phase watt-meters, one polyphase wattmeter and one voltmeter, four ammeters and portable current and potential transformers.

Two sets of calibrated gauges were used to measure the discharge head and the suction head respectively.

The Venturi meter was accepted as correct, as provided for in the contract. The manometer was checked and found correct.

All instruments were checked and calibrated in the presence of proper witnesses.

The electric meters were calibrated by means of portable standards read during the test, under the conditions of current, voltage and power-factor obtaining during the official test. As a result the master constant of the watthour meters was readjusted by eight-tenths of one per cent.

The electric motor and electric equipment were found to satisfy the conditions prescribed by the contract as to efficiency, power factor, temperature rise, slip and starting current, as well as to mechanical features.

The motor efficiency, determined under the conditions was	95.5 per cent
Slip	1.1 per cent
Temperature rise	33.5 degrees
Power-factor	90.0 per cent
Starting current (in terms of full load current)	113.0 per cent
Average line voltage	2406.0 volts

The pump and accessories satisfied the conditions of the contract as to performance, workmanship and material.

The combined efficiency of the set was found to be 82.1 per cent.

During the 28 hours official test the following conditions obtained:

Gallons pumped	37,719,500.00
Or at the rate of 32,331,000 gallons per 24 hours.	
Total dynamic head (average)	251.56
Discharge head (average)	235.13
Suction head (average)	16.43
Kilowatt-hours used	36,307.20

The contract provides for a bonus for efficiencies exceeding 76 per cent while the set is running at 30,000,000 gallons against a total dynamic head of 250 feet.

The accompanying curve sheet, figure 1, shows that the efficiencies at the other heads stipulated in the contract exceed in a similar way the guaranteed efficiencies. The service runs extending over a period of three months even showed an excess efficiency of over 5 per cent.

The average combined efficiency of the set taken to include the regular startings and to include the other conditions of varying load in regular service should not be less than 82.1 per cent by more than one per cent.

The City Meter and the Minneapolis General Electric Company's Meter have been adjusted so that they read almost exactly alike and are calibrated to agree exactly with their corrected readings taken during the official acceptance test of the pumping set. This is important, as the city is thereby enabled to purchase electric power for the pumping set on the same meter ratings as those upon which the pumping set was purchased.

In May, 1911, the city entered into a ten year contract with the Minneapolis General Electric Company, now the Northern States Power Company, by which the company agrees to furnish the necessary current of 2200 volts to operate two or more 20,000,000-gallon pumps at $4.00 per million gallons pumped against a dynamic head of 240 feet and a pumping set efficiency of 72 per cent, with the understanding that no current be used from 4.15 p.m. to 6.30 p.m., on week days during the months of November, December, January and February.

In November, 1916, a similar ten year contract was made with the same company for the operation of one 30,000,000-gallon pump.

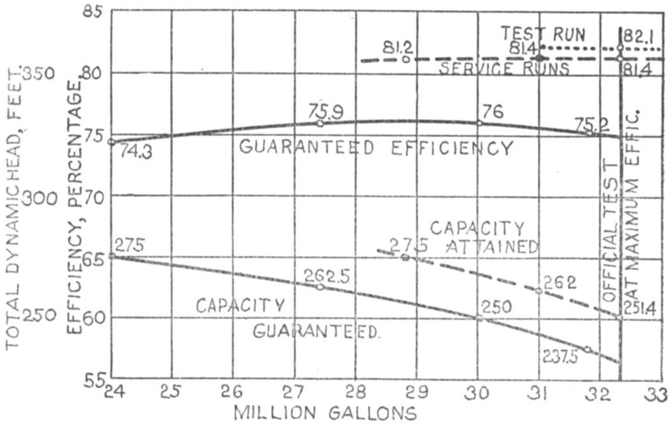

FIG. 1. GUARANTEED AND ACTUAL PERFORMANCE OF 30,000,000-GALLON ELECTRICALLY DRIVEN PUMP AT MINNEAPOLIS

The same rate of $4.00 per million gallons against 240 feet dynamic head and 72 per cent efficiency was provided in both contracts. At a different dynamic head and efficiency, the price per million gallons shall bear the same relation to the dynamic head and efficiency reached as the price above specified per million gallons bears to said 240-foot dynamic head at said 72 per cent efficiency. Both contracts also provided that the motor to be used by the city shall be capable of starting the pump in connection with which it is used from rest, when the pump is primed and when the check or gate valve in the discharge is closed, and of bringing the pump to full speed without drawing more than 150 per cent of full load current from the source of supply.

In 1910–1911, a 20,000,000 gallon Worthington pump was installed at the Northeast Pumping Station with a guaranteed efficiency of 72 per cent. During the first three months after the acceptance test of the new 30,000,000-gallon unit the following are the operating data at the Northeast Pumping Station:

DeLaval 30,000,000 gallon pump

GALLONS PUMPED	POWER COST	LABOR AND SUPPLIES	TOTAL	HEAD	EFFICIENCY
					per cent
2,797,400,000	$3.68	$2.27	$5.95	250.06	81.4

Worthington 20,000,000 gallon pump

421,340,000	$4.15	$2.27	$6.42	250.57	72.3

During the first *nine* months, the following are the operation costs per million gallons.

DeLaval 30,000,000 gallon pump

GALLONS PUMPED	POWER COST	LABOR AND SUPPLIES	TOTAL	HEAD	EFFCIENCY
					per cent
6,526,350,000	$3.72	$1.77	$5.49	255.80	82.48

Worthington 20,000,000 gallon pump

1,771,930,000	$4.33	$1.77	$6.10	257.80	71.4

At this same station there are also two triple expansion vertical A frame 15,000,000-gallon Holly pumps installed in 1903 and 1904 and tested in September, 1904. These pumps developed a duty of 162,000,000 foot pounds per 1000 pounds of steam (deductions made for slip). These pumps are in first class condition today.

During 1908 these two pumps furnished practically all the water for the city, 6,518,000,000 gallons against a head of 250 feet.

Cost of fuel* per million gallons	$3.01
Cost of labor per million gallons	3.37
Other pumping expense	.35
Total	$6.73

* Coal, Illinois screenings, $2.11 per ton.

The cost today for the same performance would be

Cost of fuel* per million gallons	$7.03
Cost of labor per million gallons	5.22
Other expense	.49
Total	$12.74

* The same coal now costs $4.93 per ton.

These figures are very interesting.

The City of Minneapolis is of course very fortunate in having the long power contracts. This was made possible by an act of the Minnesota Legislature.

It also may be of interest to engineers to learn that a representative of the Worthington Company recently stated that he thought that his Company could make the 20,000,000 gallon pump reach a similar efficiency to that of the DeLaval pump by rather inexpensive changes in its impellers. If he can, the city will be glad to give him the chance.